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WORKSHOP ON THE DESTRUCTION OF BACTERIAL SPORES HELD IN 1/1  
BRUSSELS BELGIUM 0. (U) AGRICULTURAL AND FOOD RESEARCH  
COUNCIL (ENGLAND) BRISTOL LAB T A ROBERTS 03 MAY 85  
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FINAL REPORT

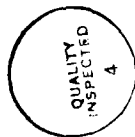
WORKSHOP ON THE DESTRUCTION OF BACTERIAL SPORES  
Brussels,  
May 1-3, 1985

Sponsored by the European Research Office of the US Army

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Our understanding of <sup>the</sup> bacteriological stability and safety of heat processed foods is based upon concepts developed some 50 years ago. Some workers believe that heat processes are much greater than necessary to achieve an adequate safety margin with a consequent loss of organoleptic and nutritional qualities.

#### Recommendations

1. The thermoresistance of bacterial spores in laboratory systems is well documented but their resistance in formulated foods is less well understood. It is recommended that heat resistance data be obtained on spores of mesophiles and thermophiles in foods representative of the range of products currently marketed and under development.
2. The heat treatment necessary to effect commercial sterility and product safety is dependent not only on the inherent heat resistance of spores but also on the numbers initially present and the extent of kill deemed necessary. It is recommended that the spore load (mesophiles and thermophiles) of foods and food components be determined.
3. Control of heat processing has improved (e.g. via computers). The sensing of temperature inside food packs during processing remains difficult and merits further investigation. This should be linked to pack/can design, and to changes in viscosity of the product.
4. While published data in general tends to show comforting agreement, the group felt that some reported data should be critically evaluated by suitable experienced persons. This could lead to the need to validate some published research in particular critical areas which impinge on heat processing, whether the proposal is to increase or decrease the

process. There is currently little incentive to validate.

5. Food stability and safety after heat processing is the consequence of several factors acting in combination, This should be more widely recognised. There is a need to understand more fully the consequences on heat processing of different initial spore numbers, product pH, levels of preservatives/food additives, storage temperature.
6. It is recommended that the 12-D<sup>60</sup> concept be re-evaluated, with a view to developing a concept of probability of spoilage, or probability of hazard, after heat treatment, which takes into account all factors known to affect resistance and spore outgrowth.
7. Ensure, especially among younger researchers, that during determination of heat resistance of microbes appropriate careful attention is paid to measurement and control of physical variables.
8. Ensure that younger researchers are made fully aware of excellent research in the older literature - sometimes published in obscure journals/books and frequently not accessible via computerised searches.
9. Ensure that those given responsibility for developing new rations are intimately acquainted with manufacturing practices of companies involved.
10. The group recognised that much recent and current research on spores, which is increasingly biochemical and genetic, will be of little or no value to food manufacturers/processors, and will not contribute to our understanding of food stability or safety. The group regarded this

trend in funding as regrettable.

11. To some extent our understanding of spore occurrence, survival and outgrowth is limited by available methodologies. Improved (rapid, specific, simple, cheap) methods are required to characterise the spore load of foods and facilitate research into the effects of processing.
12. Attempt to identify the sensitive site(s) in spores which determine their heat resistance, and elucidate the mechanism of heat activation.
13. Concern was expressed that published research on spore resistance, and our understanding of heat processing is almost entirely based on spores produced under laboratory conditions. Assurance is needed that naturally occurring spores behave similarly.
14. Aseptic packaging of low pH product was recognized as a well-established process. Much research is required to extend the process to low acid foods if microbiological safety is to be ensured e.g. develop methods to measure whether or not sterility is achieved, determine the effect of size, form and hardness of particles, develop criteria for acceptance, and means of process control and verification. Aseptic packaging of particulates appeared to pose engineering problems which require additional investigation.

Appendix 1  
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## Appendix 2

### AGENDA

Chairman: T.A. Roberts

Welcome; Introductory remarks; purpose of workshop.

#### May 1st, 1985

- |   |  |
|---|--|
| 1. Introduction: Spores & military rations  | G. Silverman<br>(US Army Labs, Natick, USA)  |
| 2. Introduction: Broad review of heat resistance of microbes in relation to heat processes applied to foods, product pH and storage | G.W. Gould (Unilever Research, Colworth, UK) |
| 3. Kinetics of cell death<br>D-value; z-value; general validity and implications; 12-D concept                                      | I. Pflug (University of Minnesota, USA)      |
| 4. Serial spores: their development and unique chemistry  | D.J. Ellar (Cambridge Univ. UK)              |
| 5. Bacterial spores: chemical/biochemical basis of heat resistance  | G.W. Gould (Unilever Research, Colworth, UK) |
| 6. Bacterial spores: spores of thermophiles   | F.F. Busta (Univ. Florida, Gainesville, USA) |

#### May 2nd, 1985

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|--|--|
| 7. Survival and inhibition of spores in meat products  | L. Leistner (Bundesanstalt für Fleischforschung, Kulmbach, FRG)    |
| 8. Heat processes in commerce<br>pasteurization, sterilization, UHT, fluidized beds, new developments - failures in commercial heat processing | K. Brown (Campden Food Research Association, Chipping Campden, UK) |
| 9. Window of acceptance in thermoprocess - principles and practice   | I. Taub (UK Army Labs., Natick, USA)                               |
| 10. Sterilization of materials and packs used in aseptic packaging   | W.M. Waites (University of Nottingham, UK)                         |
| 11. Aspects of aseptic packaging including particulates  | P.-O. Hegg (Alfa-Laval AB, Lund, Sweden)                           |

May 3rd, 1985

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|--|--|
| 12. Nutritional quality of heated products   | A.E. Bender (formerly Queen Elizabeth College, University of London, UK) |
| 13. Organoleptic quality in relation to heat processing  | T. Ohlsson, (SIK, Goteborg, Sweden)                                      |
| 14. The 12-D concept ("botulinum-cook") for low acid canned foods. Is it necessary, desirable or attained? | D.C. Kilsby (Unilever Research, Colworth, UK)                            |
| 15. General discussion: recommendations  |  |

p.m.

16. Executive Committee meeting  
(participants free to depart)

### Appendix 3

#### ABSTRACT

Introductory remarks:

T.A. Roberts

AFRC Institute of Food Research - Bristol Laboratory

Heat processing of foods for shelf-stability and safety is based on concepts developed more than half a century ago. Changing technologies in food formulation and packaging, and in methods of applying heat, demand re-appraisal of the validity of those concepts to ensure that product acceptability and nutritional quality are not being sacrificed unnecessarily by seeking unrealistic margins of safety with respect to death of bacterial spores.

Reason for workshop:

Research in the 1950's into the resistance of bacterial spores to heat concentrated on finding a unique chemical component to explain that resistance. The discovery of "dipicolinic acid" (pyridine 2:6 dicarboxylic acid) (DPA) seemed initially to explain their unique resistance.

Subsequently the isolation of DPA-less heat resistant mutants, and the involvement of calcium, indicated a more complex mechanism of resistance. Theories include a "contractile" cortex, or an "expandable" cortex, to explain the ability of the spore core to survive extreme heat, desiccation etc.

The margin of safety for heated foods remains based on Esty and Meyer's 1920's estimate of the heat resistance of spores of the soil-borne Clostridium botulinum which had been responsible for botulism in the USA.

Despite advances in crop and animal production methods, there is no means at

our disposal to guarantee that Cl. botulinum is absent from harvested animal or plant foods. Hence, in foods its spores must be killed or their growth prevented by chemicals and/or storage conditions. The heat process recommended by Esty and Meyer to assure only 1 in  $10^{12}$  chance of a spore surviving the process is c. 3 minutes at 121°F). Such severe heating is detrimental to many low acid foods but remains an accepted guideline for heat processing. Acid foods, with a pH value below 4.6, require lower heat treatments because spores are more sensitive to heat and grow less well at acid pH values. Recent international conferences on properties of spores have tended heavily towards molecular biology and genetics, overlooking entirely the interests of food processors. This has left an important gap in scientific communication.

We propose to evaluate the relevance to food processing of recent research on resistance of bacterial spores to heat, and to reappraise the need for such a severe heat process for low acid foods to ensure freedom from surviving spores of Cl. botulinum.

If it could be established that a reduced heat process would be adequate to ensure both shelf stability and safety, a significant improvement in the nutritional and organoleptic quality of the foods might result. This area will also be reviewed, as will the means by which heat is transferred to the food, and to the spores present in it, in relation to developments in methods of heat preservation.

Such considerations are highly pertinent to the remit of the US Army Research Office to provide an adequate supply of stable, safe, nutritional and desirable food supply for their forces.

4/10/85

-- ABSTRACT OF REPORT TO BE PRESENTED

AT WORKSHOP ON BACTERIAL SPORES MAY 1 - 3, 1985 --

KINETICS OF MICROBIAL SPORE DEATH, D-VALUE, z-VALUE,  
THE SEMILOGARITHMIC SURVIVOR CURVE AS A PROBABILITY CURVE,  
THE 12-D PROCESS AS A SPECIAL CASE, F-VALUES FOR  
STERILIZATION PROCESSES USING THE PROBABILITY CONCEPT

Irving J. Pflug, Professor of Food Science and Nutrition  
University of Minnesota, Minneapolis, MN

Introductory Discussion of the Need for Models in Sterilization  
Process Design, Some of the Problems in Microbial Resistance Testing  
and Other Factors That Must be Considered in the Development of  
Models and Data

Background and Development of the Semilogarithmic Destruction Model;  
Description of the Semilogarithmic Survivor Curve and Definition and  
Use of the D-Value

Review of the Bigelow Temperature Coefficient Model, the Relationship of  
the Thermal Death Time and Thermal Resistance Curves

Discussion of the Use of the Semilogarithmic Survivor Curve as a  
Probability Graph - Probabilities for Pathogenic Microorganisms,  
Clostridium botulinum,  $10^{-9}$  - Probability for Survival of Nonpathogenic,  
Mesophilic Organisms,  $10^{-6}$ , and Probability for Survival of Nonpathogenic,  
Thermophilic Organisms,  $10^{-3}$

Discussion of the 12D Process as the Special Case of the  
Semilogarithmic Destruction Model Used in a Probability Mode

Design Criteria for Sterilization Processes From a Probability Standpoint  
for Public Health and Commercial Spoilage, for Both Mesophilic and  
Thermophilic Organisms - Comments on D-Values to be Used for  
Pathogenic, Mesophilic, and Thermophilic Microorganisms

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BACTERIAL SPORES : THEIR DEVELOPMENT  
AND UNIQUE CHEMISTRY DR. D. J. ELLAR  
CAMBRIDGE UNIVERSITY U.K.

While most bacteria are equipped with metabolic systems that enable them to withstand starvation for limited periods, they eventually succumb. In contrast the ability to form a dormant spore (sporulation) enables selected bacteria (Bacillus, Clostridia) to endure starvation and stress for centuries. Bacterial spores are indeed the most dormant and stress resistant life forms on this planet. Throughout these prolonged periods of dormancy the spore retains a 'sensory' mechanism that can detect the addition of fresh nutrient sources to the environment. When this mechanism is triggered, the dormant spore germinates and normal bacterial growth and division rapidly resumes.

Spores are formed within the parent starving bacterium as a separate cell that is released upon death and lysis of the parent (mother cell). The creation of the spore is the result of a series of biochemical and morphological changes triggered by the stress of starvation. These changes involve the synthesis of unique proteins, carbohydrates and small organic molecules which together with novel spore-specific structures and a progressive dehydration of the spore during its maturation endow the spore with its unique properties. Among these changes is the development and positioning of the 'sensory' mechanism that will eventually be required to ensure the immortality of these remarkable organisms.

## BACTERIAL SPORES: CHEMICAL-BIOCHEMICAL BASIS OF HEAT RESISTANCE.

G. W. Gould

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If the osmolality around a vegetative bacterium is raised so as to exceed its osmoregulatory capacity, then water is irreversibly lost. The partly dehydrated cell becomes metabolically inactive, or 'dormant', and may increase many thousand-fold in heat resistance. In some respects, it therefore becomes spore-like.

It is now thought that, perhaps analogously, the spore forms of bacteria also maintain a very low cytoplasmic water content, but they continue to do this even when suspended in pure water or in environments with low osmolalities. It is believed that it is this lowering of water content that makes the major contribution to the extreme dormancy of these cells, and to the raising of the heat-resistance of spore components by about 40°C over that of the corresponding vegetative cell.

If lowered water content, or lowered 'internal water activity' ( $a_w$ ), are alone responsible for resistance, then it can be estimated that spores lower their cytoplasmic water contents to near 20% w/w or less, or their 'cytoplasmic  $a_w$  values' by more than 0.25 units. The mechanism by which this is achieved and maintained certainly involves the layer of electronegative peptidoglycan polymer which constitutes the cortex layer of the spore and which surrounds the central cytoplasm, though the detailed mechanism is still not fully understood.

It has been suggested that the polymer acts as an osmoregulator itself, maintaining a low water content in the enclosed cytoplasmic compartment, which contains only a low level of osmotically active species in solution and can therefore be easily dehydrated. It has been argued that polymer osmotic activity alone must be too low to maintain the cytoplasm sufficiently dehydrated, and that the cortex peptidoglycan must therefore, in addition, expand anisotropically, or contract around the cytoplasm, in such a way as to exert pressure and partially dehydrate it, i.e. through reverse osmosis. The unique spore cytoplasm component, dipicolinic acid, is probably not directly involved, but other spore specific components and molecular interactions within the cytoplasm may contribute to resistance, though again detailed mechanisms have not been worked out.

Nevertheless, it is perhaps now not so surprising that the heat resistance of spores can be varied so greatly by treatments that influence the ability of the cell to maintain a particular level of cytoplasmic dehydration. For example, further dehydration can raise resistance, whereas exposure of some spores to lysozyme, to acids, the exchange of spore cations and some other treatments that may increase hydration of the cytoplasm cause heat resistance to dramatically fall.

## BACTERIAL SPORES: SPORES OF THERMOPHILES

F. F. BUSTA

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It has been recognized for a long time that thermophiles produce spores with extreme heat resistance. Spores of Bacillus stearothermophilus exhibit high resistance but are dramatically overshadowed by the extreme resistance of those produced by thermophilic anaerobes; e.g.  $D_{121C} > 50$  min. (Xezones et al., 1965; Donnelly and Busta, 1980). Problems frequently arise from delayed germination and/or outgrowth as a result of superdormancy or conditional lethality. The former may reflect inadequate activation (Lewis et al., 1964) and the latter may involve antagonistic recovery environments or specific sensitivities to food constituents (Blocher and Busta, 1982; 1984). The injury of spores including those produced by thermophiles has been observed frequently and may influence the apparent inactivation observed after thermal treatment (Foegeding and Busta, 1981; Feeherry et al., 1985). These aspects are well demonstrated in the influence of media on the recovery of heat-damaged spores (Blocher and Busta, 1982).

The high resistance to heat by spores from thermophiles is important in food spoilage. It also is an attribute useful in biological indicator systems used to evaluate thermal processes (Pflug et al., 1980). Significantly the influence of sporulation, activation, germination, and damage play a major role in standardizing the test systems. Sporulation media and conditions affect inactivation kinetics (Busta, 1967). Germination can be modified by heat treatments (Busta and Adams, 1972; Donnelly and Busta, 1982). In general the kinetics of thermophiles are difficult to predict (Reichart, 1983; Lewis et al., 1964; Srimani and Loncin, 1980).

We remain in need of more understanding of heat resistance mechanisms. Recent dogma states that DNA is the focus of inactivation. It is a truism that if one destroys the DNA, one inactivates the microbe. Recently at the 1985 ASM Meeting, Lindsay indicated that thermophiles have one genome and mesophiles have multiples (e.g. 8). One thought is that the more genomes there are to protect by saturation with CaDPA, the more difficult it is to achieve resistance. Obviously we do not have a complete understanding or agreement on the source(s) of resistance. Teixeira et al., (1985) have also investigated heat transfer in bioindicator units indicating that minor differences in heat transfer can result in apparent differences in heat resistance. They are concentrating on methodologies to ultimately standardize spore suspensions with biochemical and physical treatments.

Thermophiles and their spores must be considered in the overall design of thermal processes because thermophilic spoilage or biological indicator responses may ultimately be the deciding design parameters. They also may eventually assist in understanding spore heat resistance.

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Survival and Inhibition of Spores in  
Meat Products\*

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Canned meat products should be safe and stable as well as delicious and nutritious. Since meat products are low-acid foods, they were heated to  $F > 4.0$ , in order to be storable without refrigeration.

It was postulated that meat products should be processed in hermetically sealed containers and intensive enough to inactivate all mesophilic microorganisms, including spores of the genera Bacillus and Clostridium. The detrimental effects of an exposure of the food to high temperatures have been diminished by rotation autoclaves and/or HTST (high temperature short time processes).

For economic reasons the original containers of canned meats, i.e. metal boxes or glass jars, were partly replaced by pouches or even by casings closed by clips. For heat processing of pouches and sausages in casings autoclaves with a diligent controlled counter pressure are essential.

Based on the heat process applied, canned meats were classified into tropical, fully, three-quarter and semi preserved products, and for three-quarter and semi preserved meats refrigeration storage of the product at 10 or 5°C, respectively, is required; i.e. the surviving bacilli and clostridia will be inhibited by decreased storage temperature. However, the growth of surviving sporeformers alternatively could be inhibited by other hurdles, e.g.  $a_w$  and/or pH. Therefore, also for 'canned' meat products the 'Hurdle Technology' is promising.

Based on 'Hurdle Technology' are Shelf Stable Products (SSP), which are grouped into  $a_w$ -SSP, pH-SSP and F-SSP, according to the hurdle most important for their stability. SSP are heated gentle but sufficient to inactivate all non-sporing organisms, and recontamination is avoided by the sealed container. The mild heat treatment improves the sensoric and nutritional properties of the product and saves energy. Growth of surviving bacilli and clostridia is inhibited in SSP by a sufficient decrease of  $a_w$ , pH

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\* Presented at the 'Workshop on Bacterial Spores', held May 1 - 3, 1985 at Brussels

and Eh. Nitrite contributes somewhat to the stability of SSP in Bologna type sausage, but little in liver and blood sausages. SSP are storable without refrigeration.

Primarily based on decreased water activity are  $a_w$ -SSP. They are heated to an internal temperature of 70 - 80°C and are adjusted to  $a_w < 0,95$ , this is sufficient to inhibit spore-formers, including C. botulinum, in these products. Traditional  $a_w$ -SSP are Italian Mortadella and German Brühdauerwurst, both products have an untarnished safety record and are storable for months without refrigeration.

Primarily based on a relatively low acidity are pH-SSP, heated to an internal temperature of 65 - 80°C and adjusted to a pH < 5.4. Traditional products of this type are browns and Gelderse Rookwurst. The latter is a product of The Netherlands, and if heated in a sealed pouche it may be stored for several weeks at room temperature.

A recent development are 'autoclaved sausages' heated in counter pressure autoclaves to F values of about 0.1 - 0.4. Such products are sold in large quantities in West Germany by dynamic discount chains without refrigeration. Since the stability of 'autoclaved sausages' is apparently primarily based on a sublethal damage of bacterial spores, as well as on additional hurdles, they are called F-SSP. We investigated the stability of such F-SSP and suggested the following conditions for safe products: i. Spore-count in the heated product should be low; ii. F-value > 0.4; iii.  $a_w < 0.97$  (for Bologna type sausage, because nitrite contributes somewhat to stability) or  $a_w < 0.96$  (for liver and blood sausages, because in these products nitrite is not effective). iv. pH < 6.5; v. Eh (redox potential) should be low. Therefore, the stability of F-SSP could be based on a 'Magic Square', i.e. on a sensible combination of the hurdles F,  $a_w$ , pH and Eh.

Reliable methods are available for measuring F,  $a_w$  and pH, but not for Eh. However, the measurement and adjustment of Eh is of particular importance for the inhibition of growth of the aerobic sporeformers in meat products, since bacilli are inhibited already at a much higher  $a_w$  if the Eh is low. Therefore, at present we investigate the improvement of methods for measurement of Eh, which should become as reliable as  $a_w$  measurements to-day.

It is feasible that by 'Hurdle Technology' based on the 'Magic Square' a new generation of 'canned' meat products could emerge, which are safe and stable without refrigeration and have superior sensoric and nutritional properties, in spite of or due to the mild heat treatment. The quantitative aspects of the hurdles needed in products based on 'Hurdle Technology' require an exact definition based on experimental work with the particular product. It is foreseeable that meat processing, including 'canning', will become more complicated and sophisticated, however, also better optimized than in the past.

Sterilisation of materials and packs  
used in aseptic packaging.

W.M. Waites

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Aseptic packaging is used in conjunction with pasteurisation or ultra high temperature (UHT) heat processing to extend the shelf life of perishable food (Anon., Food Engineering International, 1984 (1-2) 24-50). Compared to packaging with glass or steel, aseptic packaging uses lighter, one trip materials and is roughly half as expensive (Anon, 1983, Food Engineering 55 (7), 82-83) and UHT processed foods often have a more acceptable flavour and texture and better nutritional quality than canned foods.

Aseptic packaging is either plastic or a laminate of polyethylene, aluminium foil, polyethylene and paperboard (Fisher, 1981, Food Manufacture 58 (8) 25, 27). In the laminate package, aluminium foil serves as a light and gas barrier while the cellulose paper layer gives rigidity and strength and the polyethylene inner coat contains the product and forms the pack seals. Both plastic and laminate containers may be sterilised by  $\gamma$ -irradiation or by chemicals. Irradiation has a higher capital cost than chemical sterilisation which usually employs hydrogen peroxide.

With one exception, hydrogen peroxide is applied at 35% before being heated to between 110 and 120°C. Such heating is required to evaporate and decompose the hydrogen peroxide, since FDA regulations limit the concentration in the pack to 100 ppb and 1 ppb immediately and 24h after filling respectively. The time and temperature of heating are critical since the polyethylene packaging surface softens and melts after 3s at 100°C (Perkin, 1982, Dairy Industries International 47 (3) 20-22). In an alternative method of sterilisation, 1% or less of hydrogen peroxide is employed and irradiation with ultra-violet light, rather than heating, is used to initiate decomposition. Both heat and UV irradiation produce a chain reaction within the hydrogen peroxide, the first step resulting in the formation of free hydroxyl radicals which kill microorganisms rapidly when formed either close to or within cells and eventually produce water and oxygen (Waites & Peel, 1983, Nutrition and Food Science, 81, 12-13) without the formation of any stable, toxic intermediates.

"Aspects of continuous sterilization with special  
emphasis on particulate food"

Per-Olof Hegg  
Alfa-Laval Food & Dairy Engineering AB  
Lund, Sweden

There are several driving forces for the development of continuous sterilization of food. Some of these derive from the market, others are given impetus for cost reasons and still others are concerned with the availability of new technology and new materials, chiefly, in the packaging field.

It seems as if we currently are seeing "the third wave" of aseptic development, where aseptic processing and packaging of particulates might be established as firmly on the market as the first and second "wave" established UHT-milk, aseptic juices and milk based products.

It is, however, clear that there exist many barriers to continuous sterilization of low-acid or neutral particulate food. The following are examples where basic work is needed:

heat penetration into particles, residence time distribution, reinfection, criteria for acceptability, methods to measure sterility, scaling from laboratory and pilot plant experiments, product recipe change etc.

Of course there are also many engineering considerations for the designer of a continuous sterilization process. Apart from the heat exchanger the pumps and valves are of major importance. The requirements on these concern for instance: steady flow with minimum slippage and unambiguous closure to prevent reinfection. In many applications it is also important that these components do not impart excessive damage to the particles. In these areas a lot of specialized knowledge is required, and many variations are tried.

## THE EFFECT OF HEAT PROCESSING ON NUTRITIONAL VALUE OF FOODS

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There is a popular belief that all processed foods are nutritionally inferior to those prepared by the housewife; hence the current denigration of convenience, processed and fast foods. In fact each process and each food, and often each factory and each housewife, has to be considered separately, but as a generalisation it is likely that a factory under the control of a competent food technologist can produce foods nutritionally superior to those produced by an average housewife.

Most processes involve heat such as canning, bottling, sterilisation, pasteurization and blanching, and so any losses that occur replace part, or even all of the losses that take place in domestic food preparation.

The greatest losses are due to the extraction of water-soluble nutrients - particularly vitamin C and the B vitamins, and dry heat damages only thiamin, and vitamin C, and reduces the quality of protein. The last has been much investigated and recent conclusions are that damage to protein quality has little effect in the total diet.

A number of principles need to be borne in mind:-

1. Some losses are inevitable even under controlled, laboratory conditions - such as baking of bread (loss of thiamin and available lysine); in cooking; in preservation both by heat and chemicals (sulphur dioxide

destroys thiamin); in the blanching process that precedes freezing.

2. Heat treatment can confer specific benefits - destruction of toxins in legumes; synthesis of niacin in roasting coffee; destruction of anti-enzymes and thiaminase; as well as the preservation of food.
3. When comparisons are made between foods prepared freshly or after processing, this must be made 'on the plate' not simply between raw and processed foods.
4. Losses must be considered in relation to the diet as a whole since some foods play only a small part in the diet. However, foods intended for vulnerable groups of the population, especially infants, must be carefully considered since they may constitute a very large part of the diet.
5. It is possible to reduce some of the inevitable losses by improved factory procedures.
6. The manufacturer has an advantage over the housewife since his raw material is fresher (garden fresh) than that available to the housewife (market fresh) - a matter that affects probably only vitamin C and folic acid.
7. There is often a considerable difference between what should take place, as indicated from model systems and laboratory experiments, and what does take place in the factory.
8. When losses do occur the choice is often not between processed foods and fresh foods but between processed foods and none at all.

In general, looking back on processes that were established before much was known about nutrients there is no evidence for concern at any losses, but looking forward to novel processes (such as extrusion cooking and irradiation) it is essential to consider nutritional value as well as safety if foods so treated are expected to replace traditional foods to any extent.

## ORGANOLEPTIC QUALITY IN RELATION TO HEAT PROCESSING

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### ABSTRACT

The theoretical concepts of the inactivation of bacterial during heat processing spores was developed many years ago. There is also a fair amount of experimental data available. For the thermal degradation of nutrients and other components, there are well established concepts of reaction kinetics. Some systematic experimental data on nutrients are also available. From the product acceptability point of view there is little systematic data available on the effect of heat processing on the sensory quality.

In our R&D on optimizing the sensory quality of thermal processed foods we have seen a need to develop systematic data on the effect of heat on the sensory quality. To evaluate the effect of various temperatures and times on the sensory attributes of processed foods we are using the so called cook-value (C-value), defined in analogy to the well-known  $F_0$ -value. The cook-value can be interpreted as the amount of heat needed to reach a given change in the sensory quality of the food; e.g softening of texture. In many sterilization processes the heating is so severe that the object is to minimize the loss of the sensory quality; and thus minimize the overall cook-value.

We have performed experiments to determine cook-values and its temperature dependence for a number of foods. These were processed in thin cans at different temperatures. The sensory analysis panels evaluated the samples, and the sensory data was used to determine the temperatures dependence of the sensory quality deterioration; the z-values. They varied from 15 to 33°C with an average of 24°C.

We have also determined the time needed to reach a desired sensory quality e.g softening of texture in potatoes. The temperature dependence was 17°C. The required C-values varied between 4 and 16 depending on maturity and other factors. Cook-values for the optimum cooked texture of other canned vegetables are also available.

The cook-value concept has been very useful in studies of optimizing the heat treatment of sterilized foods, as some applications will demonstrate. Calculations of the heat transfer in heat processing of flat containers e.g retort pouches show that minimum cook-values are reached at 127-130°C for 20 mm thickness.

For normal cylindrical cans minimum cook-values are found at temperatures slightly lower than 120°C. We have also tried to extend the results to foods with some convection heat transfer utilizing the  $f_h$ -slope value from heat penetration measurements. Optimal sterilization temperatures determined in calculations agree well with sensory analysis data both for baby foods and whole potatoes.

The cook-value is a good tool for R&D, but should be used with caution. It does not in any way replace sensory analysis.

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